• CE Amplifier without by passed capacitor

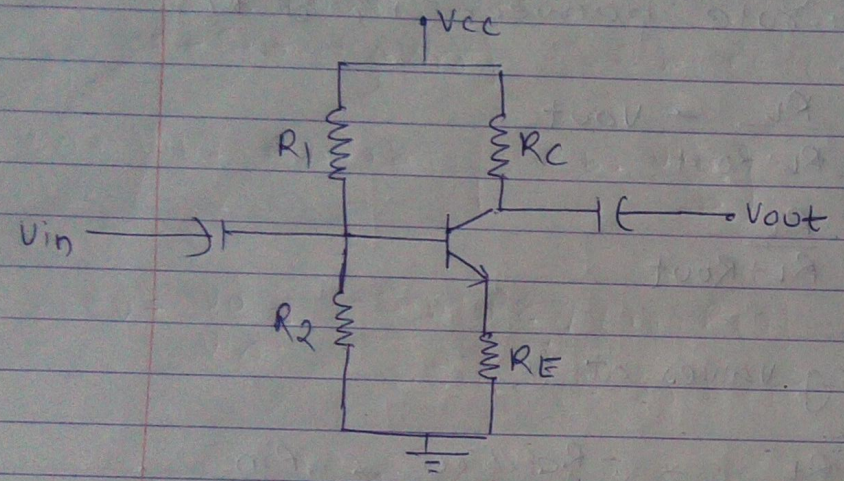


fig: CE amplifier ckt without bypassed capacitor (CE)

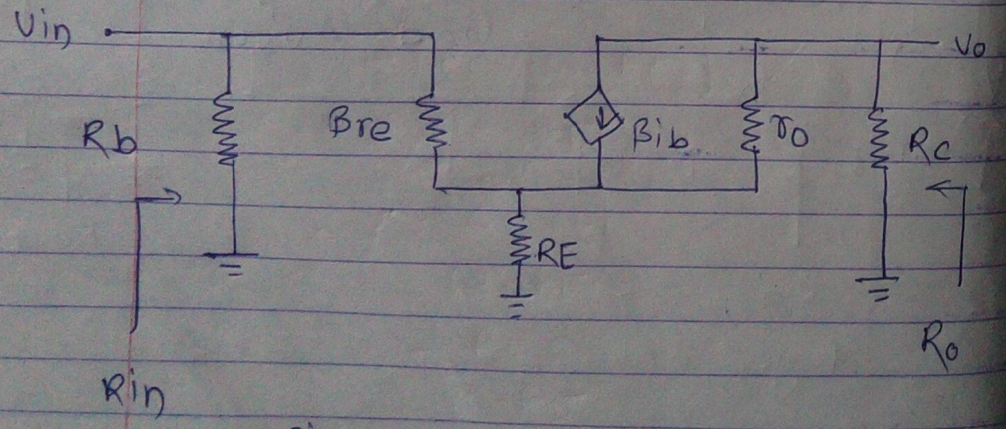


fig: re-model

finding Rin:

$$\therefore V_{ib} = \beta r_e i_b + (\beta+1) i_b R_E$$
$$\frac{V_{ib}}{i_b} = \beta r_e + (\beta+1) R_E$$
$$R_{ib} = \beta r_e + (\beta+1) R_E$$

$$R_{in} = R_b // [\beta r_e + (\beta+1) R_E]$$

$\beta >> 1$, $\beta + 1 = \beta$

$$R_{in} = R_b // (\beta r_e + \beta R_E)$$
$$= R_b // \beta (r_e + R_E) \quad [\because R_b \geq 10 \beta r_e]$$
$$= \beta (r_e + R_E)$$
$$= \beta R_E$$

At open (ie R_C not included) r_o is max and R_E is minimum.

$$R_{oc} = r_o + R_E$$
$$r_o >> R_E$$
$$R_{oc} \simeq r_o$$

Or,

$$R_{out} = R_{oc} // R_C$$
$$= r_o // R_C$$
$$\simeq R_C \quad (r_o >> R_C \text{ at open})$$

finding Av;

$V_o = i_o \cdot R_{out}$

$= -i_c R_{out}$

$= -\beta i_b [R_c // r_o] = -\beta i_b [R_c // (r_o + R_E)]$

$V_{in} = V_{ib} = R_{ib} \, i_b \quad \left[\because R_{ib} = \frac{V_{ib}}{i_b}\right]$

$\therefore A_v = \frac{V_o}{V_{in}} = \frac{-\beta i_b [R_c // (r_o + R_E)]}{i_b \beta r_e + (\beta + 1) i_b R_E}$

$= \frac{-\beta i_b [R_c // (r_o + R_E)]}{i_b [\beta r_e + (\beta + 1) R_E]}$

$= \frac{-\beta [R_c // (r_o + R_E)]}{\beta r_e + \beta R_E}$

$= \frac{-[R_c // (r_o + R_E)]}{r_e + R_E}$

$= \frac{-(R_c // r_o)}{r_e + R_E}$

$= \frac{-R_c}{r_e + R_E}$

$A_i = \frac{i_o}{i_{in}} = \frac{i_o}{i_b} * \frac{i_b}{i_{in}}$

$= -\beta \frac{R_b}{R_b + R_{ib}}$

$= -\beta$

Comparison between the common emitter amplifier ckt with RE and without RE and excluding.

Rs and Rc

from the analysis of CE amplifier ckt with and without RE and with and without Rs and RL, we absorbed and including an emitter resistor RE in the amplifier ckt results in the following characteristics;

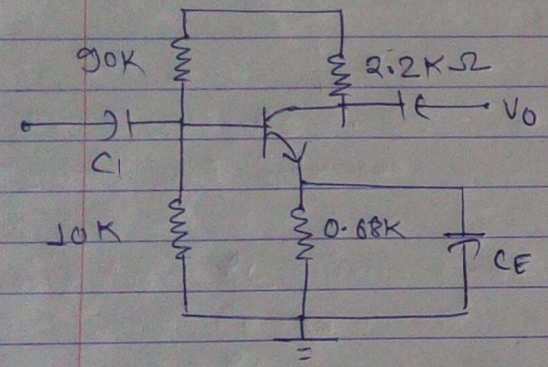
1) Rib is increased by the factor $(\beta+1)RE$
2) A_{vo} is reduced from $-\frac{R_c // r_o}{r_e}$ to $\frac{-R_c // r_o}{r_e + R_E}$ or it is reduced from $\frac{R_c}{r_e}$ to $\frac{R_c}{R_E + r_e}$

3) It means the frequency response of the ckt significantly increased (improved)

Numerical: 1

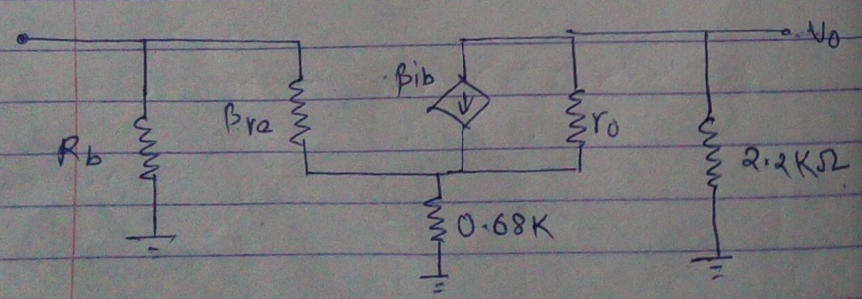
for the N/W of figure below (with CE unbypa-ssed), determine (using approximate approximation)

a. r_e b. Z_i c. Z_o and d. A_V



Soln,

preparing re-model



$\{\beta R_E > 10 R_2\}$

Now,

$R_b = 90 // 10$

$= \frac{90 * 10}{90 + 10}$

$= \frac{900}{100}$

$= 9K\Omega$

$V_B = \frac{R_2}{R_1 + R_2} * 16$

$= \frac{10}{10 + 90} * 16$

$= 1.6V$

$V_E = V_B - V_{BE} = (1.6V - 0.7V) = 0.9V$

So, $i_E = \frac{V_E}{R_E} = \frac{0.9V}{0.68K} = 1.32mA$

(a) $r_e = \frac{26mV}{1.32mA} = 19.64\Omega$

(b) $Z_{in} \simeq R_{in}$ [Testing condn; $r_o \geq 10R_C$ or, $r_o \geq 10(R_C + R_E)$]

$R_b = R_1 // R_2 = 9K\Omega$

$Z_b = \beta R_E$

$Z_{in} = 9K\Omega // \beta R_E$

$= 9K\Omega // 142.80$

$= 8.466401K\Omega$

(c) $Z_{out} = R_C$

$= 2.2K\Omega$

(d) $A_V = \frac{-R_C}{R_E + r_o}$

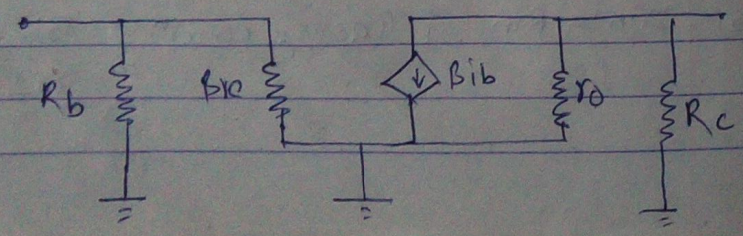
$= \frac{-R_C}{R_E}$

$= \frac{-2.2}{0.68}$

$= -3.2350$

Also Dopeat with CF connected

(e)



(a) $Z_{in} = R_b // R_{ib}$

~~$= (R_1 // R_2) //$~~

since $R_b \geq 10\beta r_e$

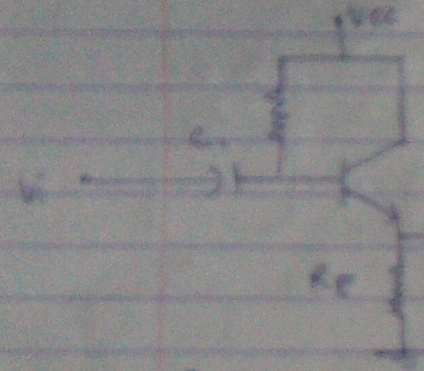
$R_{in} = \beta r_e$

$= 210 * 39.64$

$=$

$i_b = \frac{V_B - V_{BE}}{R_2}$

Emitter Follower Amplifier:-



Since collector is directly connected to the collector grounded with ac signal is CC config

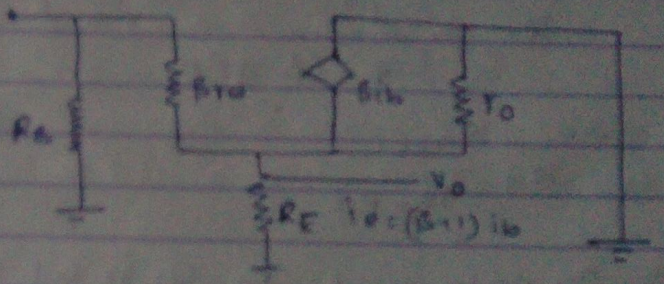
Fig: Emitter follower circuit

- Where the O/P is taken from the emitter terminal of the transistor as shown in the figure which reflects Emitter follower
- It is slightly less than Vin because of the drop of B-E Junction But AV=1 (good)
- Since Vc VE is in same phase with the signal Vin, Ie and Ib attain their +ve cycle +ve half cycles at the same point of time It follows Vin, hence called Emitter follower
- Though emitter is given of grounded but in AC analysis
- Collector is assumed to be grounded → so common collector

Impedance:-

2. Used for impedance matching purpose. i.e; It present high impedance at the i/p and low at o/p. So high Zi and low Zo is used as buffer or isolation ckt

AC Analysis:



So,

$Z_{in} = R_b \parallel Z_b$

$Z_b = \beta r_a + (\beta+1) R_E$

$Z_b = \beta(r_a + R_E)$ [$\because \beta+1 \approx \beta$]

Since $R_E >> r_a$

$Z_b = \beta R_E$

And o/p impedence;

$$i_b = \frac{v_{ib}}{R_{ib}}$$

$$\text{or, } (\beta+1) i_b = (\beta+1) \frac{v_{ib}}{R_{ib}}$$

$$\text{or, } i_e = (\beta+1) \frac{v_i}{z_b} \quad [R_{ib} = z_b]$$

or,

$$i_e = \frac{(\beta+1) v_i}{\beta r_e + (\beta+1) R_E}$$

or,

$$i_e = \frac{v_i}{r_e + R_E}$$

To determine z_o, v_i is set to zero.

And,

$$z_o = R_E \,//\, \beta r_e$$

$$z_o = \beta r_e \quad [R_E >> \beta r_e]$$

Now applying voltage divider rule,

$$v_o = \frac{R_E}{R_E + \beta r_e} \cdot v_i$$

$$\text{or, } \frac{v_o}{v_i} = \frac{R_E}{R_E + \beta r_e}$$

$$\therefore A_v = \frac{R_E}{R_E + \beta r_e} \simeq 1$$

Alternative method for A_v

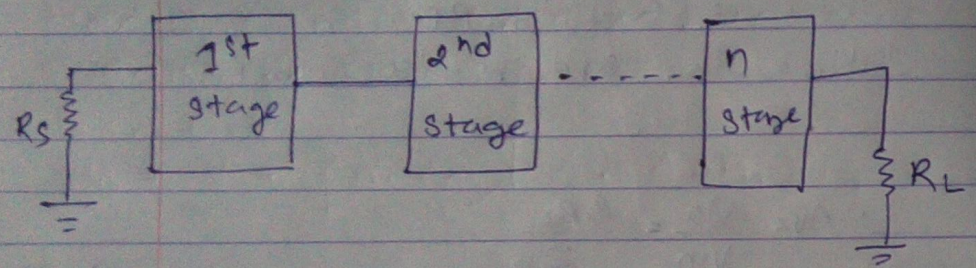
$$v_o = i_e \cdot R_E$$

$$= (\beta+1) i_b \cdot R_E$$

$$v_{in} = v_{ib} = \beta r_e \cdot i_b + (\beta+1) i_b \cdot R_E$$

$$\therefore A_v = \frac{v_o}{v_{in}} = \frac{\beta R_C}{z_b}$$

Multistage Amplifiers:



Overall voltage gain = V_L/V_S

Overall voltage gain = $A_1 * A_2 * A_3 \cdots A_{n-1} * A_n$

Overall voltage gain is equal to the product of the individual gain of the stages of amplifier.

$A < A_1 * A_2 * A_3 \cdots A_n$ [Due to loading effect or shunting effect]

practical;

$20\log_{10}(A) = 20\log_{10}(A_1) + 20\log_{10}(A_2) + \cdots 20\log_{10}(A_n)$

Overall voltage gain in n-stage Amplifier:

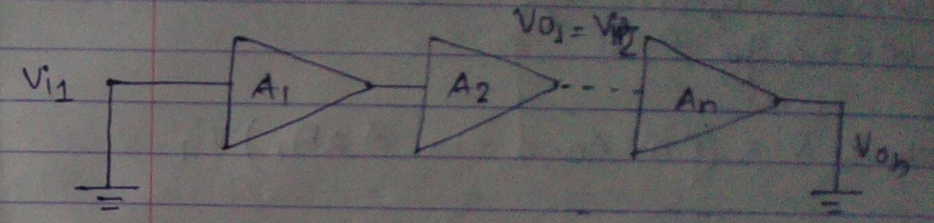


fig: n-amplifier stages connected in cascaded ie the o/p of one stage is the i/p to the next stage.

By Definition;

$V_{o1} = A_1 V_{i1}$ — (i)

Also,

$V_{o2} = A_2 V_{i2} = A_2 V_{o1}$ — (ii) [$V_{i2} = V_{o1}$]

Now substituting eqn (i) in eq (ii)

$V_{o2} = A_2 \cdot A_1 \cdot V_{i1}$ — (iii)

Similarly;

$V_{o3} = A_3 \cdot V_{i3} = A_3 V_{o2}$ [$V_{i3} = V_{o2}$]

$V_{o_2} = A_2 \cdot A_2 \cdot A_1 \cdot V_{i_1}$

Hence continuing in this manner we eventually find;

$V_{o_n} = V_i = (A_n \cdot A_{n-1} \cdots A_2 A_1) V_{i_1}$

$$\Rightarrow \frac{V_{o_n}}{V_{i_1}} = A_n * A_{n-1} \cdots A_2 * A_1 \quad \text{— (IV)}$$

so eqn (IV) is overall voltage gain of the n-cascade system, which is equal to the product of the gain of n-individual system.

Note 1:
If one of the amplifier stage is (-ve) the overall voltage gain is 180° out of phase

Note 2:
if n = odd, then no effect
n = even

This implies overall voltage gain in dB =

$$20\log_{10}\left(\frac{V_{o_n}}{V_{I_1}}\right) = 20\log_{10}\left[A_n * A_{n-1} * \cdots A_2 A_1\right]$$

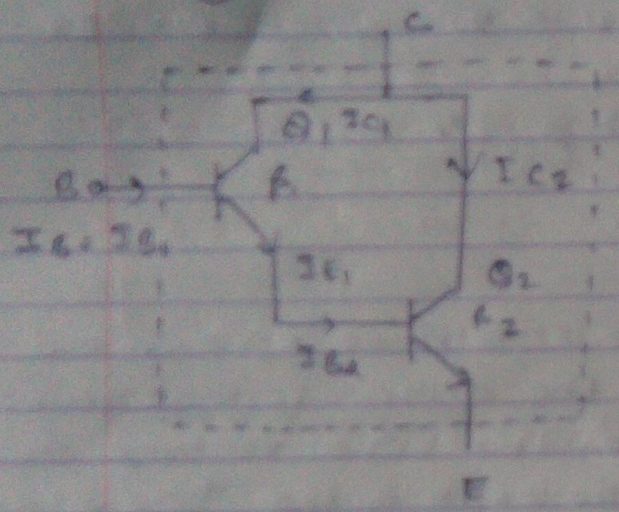
Note 3:
effect of source resistance (R_S) and load resistance (R_L) on the overall voltage gain:

R_S causes the usual voltage division to take place at the input to the 1st stage and R_L causes the voltage division to occur between R_L and the output resistance of last stage.

Under these circumstances the overall voltage gain of n-cascated system with R_S and R_L will be;

$$\frac{V_L}{V_S} = \left(\frac{R_{in_1}}{R_S + R_{in_1}}\right) * A_n * A_{n-1} \cdots A_2 * A_1 * \left(\frac{R_L}{R_L + r_{on}}\right)$$

Darlington pair Amplifier:



When the collector of two BJT's are tied together the emitter of transistor is directly coupled to the based of the 2nd transistor such configuration is called darlington pair.

Let β_1 & β_2 be the dc-β values of transistor Q_1 and Q_2 respectively.

We know,

$$I_{C_1} = \beta I_{B_1}$$

$$I_{E_1} = (\beta_1 + 1) I_{B_1}$$

From fig.

$$I_{E_1} = I_{B_2}$$

$$\therefore I_{C_2} = \beta_2 I_{B_2}$$

$$= \beta_2 (\beta_1 + 1) I_{B_1}$$

Since $I_C = I_{C_1} + I_{C_2}$

$$= \beta_1 I_{B_1} + \beta_2 (\beta_1 + 1) I_{B_1}$$

$$= I_{B_1} [\beta_1 + \beta_2 (\beta_1 + 1)]$$

$$= (\beta_1 + \beta_2) I_{B_1} + \beta_1 \beta_2 I_{B_1}$$

And $I_B = I_{B_1}$

So,

$$I_C = (\beta_1 + \beta_2) I_B + \beta_1 \beta_2 I_B$$

or, $\frac{I_C}{I_B} = \beta_1 + \beta_2 + \beta_1 \beta_2$

$\therefore \beta_{DP} = \beta_1 + \beta_2 + \beta_1 \beta_2$

Since,

$\beta_1 \beta_2 \gg \beta_1 + \beta_2$

$\beta_{DP} = \beta_1 \beta_2$

i.e.,

$\beta_1 = \beta_2 = \beta$

$\beta_{DP} = \beta^2$

Hence the Darling pair is also called superBeta.

Small-signal ...ysis of Darlington Pair
To determine th... effective small I/p
resistance from B... E function.

$$r_{e_2} = \frac{26mV}{I_{E_2}}$$

looking into the ...se of transistor Q_2

$$r_{in(Base)_2} = \ldots_2$$

$$r_{e_1} = \frac{26mV}{I_{e_1}}$$

$$I_{E_1} = \frac{I_{E_2}}{\beta_2}$$

$$I_{E_2} = (\beta_2 + 1) I_{B_2}$$
$$\text{or } I_{E_2} = (\beta_2 + 1) I_{E_1}$$
$$\text{or } \frac{I_{E_2}}{I_{E_1}} = \beta_2$$

$$r_{e_1} = \beta_2 \left(\frac{26mV}{I_{E_2}} \right)$$

Now,

~~$r_{in\,Dp} = \beta_1 r_{e_1} \ldots r_{e_2}$~~
~~$= \beta_1 \times \left(\frac{26mV}{I_{E_2}} \right)$~~

$$r_{in_{DP}} = \beta_1 (r_{e_1} + \ldots \text{ Base}_2)$$

~~$= \beta_1 (r$~~

It is the ...ective resistance looking into the ba... of Q_1 across the

effective small signal input resistance.

composite base to emitter terminal.
$r_{in\,DP}$ is the effective resistance of small signal effect of Darlington pair

$$r_{in_{Dp}} = \beta_1 (r_{e_1} + \beta_2 r_{e_2})$$

$$= \beta_1 (\beta_2 r_{e_2} + \beta_2 r_{e_2})$$

$$= 2\beta_1 \beta_2 r_e$$

$$r_{e(DP)} = \frac{r_{in(DP)}}{\beta_{DP}}$$

When the load is connected at the output of the darlington pair configuration then the total input resistance to the follower circuit is,

$$r_{in} = r_{in_{DP}} + \beta_{DP} r_L$$